Investigation of Performance Properties of Graphene Coated Fabrics

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ABSTRACT: *Graphene is a material that attracts attention in technical textile applications as in many other areas due to its outstanding features. In this study, it was aimed to investigate the performance properties of graphene coated fabrics. Pre-treated polyester fabrics were coated with nano-graphene powders at different concentration rates (50, 100 and 200 g/kg) by knife-over-roll technique. According to test results, generally, the graphene coating had a positive effect on the performance properties of polyester fabrics.*

KEYWORDS –*Bending rigidity, bursting strength, graphene, tear strength, textile coating*

I.INTRODUCTION

Technical textiles which have enormous product diversity is the fastest growing area of the textile sector. Technical textiles researches have gained importance especially in recent years [1].The coating is used for technical textile production to achieve functional properties to fabrics and increasing usage areas of fabrics [2]. The coated fabric is the surface formed by the joining of two or more layers, at least one of which is a textile surface and at least one of which is a polymeric layer. When investigating commercial scope, it is seen that coated fabrics are used frequently in technical textile products [3].

In the literature, there were some studies about performance properties of coated fabrics. Kadem and Tölek [4] investigated performance properties of coated denim fabrics. In order to determine the effect of coating on performance properties, fabric thickness, tensile strength, abrasion resistance, air permeability, water vapor resistance, pilling, fabric stiffness tests were performed. Coated fabrics had higher weight (g/m^2) values. Tensile strength, pilling and abrasion resistance properties increased. Water vapor resistance properties and thickness values decreased. The authors claimed that similar results have been reached with studies in the literature. Kut and Gunesoglu [5] polyurethane and polyacrylate coating process applied to the woven fabric, tensile strength, abrasion resistance, waterproofing etc. changes in various performance characteristics evaluated. According to the results, it was determined that the coating increased the tensile strength of the fabric and the highest increase was in the polyurethane coated fabrics. In polyurethane and polyacrylate coating fabrics, there was not much difference in wear resistance, and the polyacrylate coating fabric has the highest waterproof performance.

Graphene has become rapidly fast growing material in nanomaterial research as it is the thinnest two-dimensional network of atomically thick carbon atoms arranged in a hexagonal honeycomb lattice structure [6]. Graphene, which has abundant availability in nature, is currently under research for its functional applications in the field of textiles [7].

In the literature, generally, studies focused on using graphene and its derivatives in composite structures and usually solution coating [8, 9, 10, 11 etc.]. However, using graphene on paste form coating to the fabrics has not been studied yet.

In this study, it was aimed to investigate performance properties of graphene coated polyester fabrics. For this purpose, fabrics were coated with graphene nanopowders at different concentrations by knife-over-roll technique. Thickness, fabric weight, bending rigidity, abrasion resistance, tear strength and bursting strength tests were performed.

II.MATERIAL AND METHOD

II. 1 Material

Pre-treated 100 % polyester woven fabrics were used. Properties of woven fabrics were given in Table 1.

TABLE 1

Properties of woven fabric

Property	Warp	Weft
Raw material	Polyester	
Density (1/cm)	30	18
Fabric structure	Plain weave	

Graphene which has nanoparticle size was used as coating material. It was supplied from Grafen Chemical Industries (Grafen Co.), and properties were given in Table 2.

TABLE 2

Properties of graphene

Particle size (nm)	50-100
Purity (%)	96-99
Surface area (m^2/g)	13-15

Coating chemicals; binder, fixator, thickener and anti-foam agent were supplied from Rudolf-Duraner (Turkey), and their properties were given in Table 3.

TABLE 3

Properties of coating chemicals

Chemical	Property
Binder	Acrylic binder, anionic/nonionic
Fixation agent	The butanone oxime-free blocked isocyanate-based crosslinking agent, anionic
Synthetic thickener	Neutralized polyacrylate, anionic
Anti-foam agent	Hydrocarbons, ethoxylated fatty acids and silicic acid combination, nonionic
Ammonia	25% liquid
Water	Reverse osmosis soft water

Reference (R_1, R_2) and coated fabric codes were given in Table 4.

TABLE 4

Sample Codes

Graphene Concentration (g/ kg)	Sample Code
0	R_1
0	R_2
50	GR 50
100	GR100
200	GR 200

**R₁: Raw fabric, *R₂: Coated fabric which has not filler material (graphene)*

II. 2 Method

II. 2. 1 Preparing coating paste

The coating paste was prepared with mixing coating chemicals (Table 3) and graphene nanopowders at 50, 100, 200 g/kg concentration rates. Viscosity values of coating pastes varied in the range of 7000 ± 200 centipoises. Brookfield RVT analog viscometer was used for viscosity measurements.

II. 2. 2 Coating and fixation

Pre-treated 100% polyester woven fabrics were coated with graphene nanopowders by knife coating technique on a laboratory type coating machine (Ataç GK 40 RKL). Coatings were made according to knife over roll principle (Fig. 1.) and the sharp pointed knife was used.

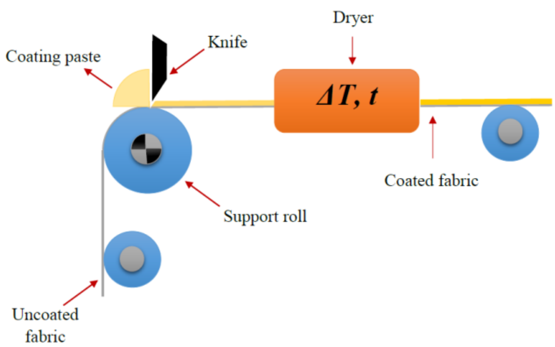

Fig. 1. Knife over roll coating schematic view

The distance between the knife and fabric were arranged as 0.5 mm. Samples were dried at 100˚C for 10 minutes and they were fixed at 160˚C for 3 minutes on a laboratory type steamer (Rapid H-TS-3).

II. 2. 3 Performance Tests

Thickness measurements of coated fabrics were made according to TS 7128 EN ISO 5084 standard with James Heal's R & B Cloth thickness tester. Three measurements were taken for each fabric and the average thickness values of the fabrics were determined by taking averages between them.

The measurement of the fabric weights was carried out by the TS 251 standard. Each sample was weighed three times on a precision scale and the average value was calculated.

Bending rigidity of samples was measured with SDL Atlas Fabric Stiffness Tester according to TS 1409 standard. Three coated fabrics were chosen for each concentration rate.

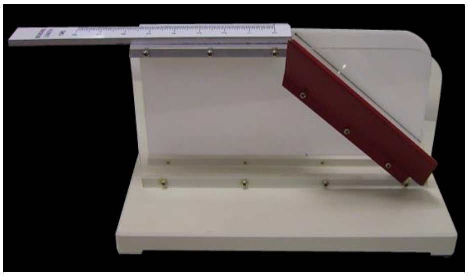

Fig. 2. Fabric stiffness tester [12].

Equations (1), (2) and (3) were used to calculate bending length, flexural rigidity and overall flexural rigidity respectively.

$$c = \frac{l}{2} \qquad (1)$$

c is; bending length (cm), l is the length of overhang (cm)

$$G = 0.1 \times W \times c^3 \qquad (2)$$

G is flexural rigidity (mg.cm), W is fabric weight (g/m^2)

$$G_0 = \sqrt{G_a} \times \sqrt{G_c} \qquad (3)$$

G_0 is overall flexural rigidity (mg.cm), G_a is weft flexural rigidity, G_c is warp flexural rigidity.

Measurement of abrasion resistance of fabrics was performed according to TS EN ISO 12947-3 by Martindale Method- Determination of Weight Loss. Two samples were taken for each concentration rate and the percent weight loss was calculated after 30.000, 50.000 and 100.000 cycles.

Fig. 3. Abrasion and pilling tester [13].

Tear strength measurements of fabrics were made according to ASTM D 1424 (Elmendorf) standard. Three measurements were taken in warp and weft directions.

Fig. 4. Elmendorf tearing tester [14].

Bursting strength measurements of fabrics were performed with Shimadzu tensile tester according to TS 7126 (ball-bursting strength) standard. The sample size (Ø) was 44.45 mm and ball size (Ø) was 25.4 mm. Test speed was 305 mm/min.

Fig. 5. Shimadzu tensile tester

III.RESULT AND DISCUSSION

III. 1 Thickness and Weight Results

Weight (g/m^2) and thickness measurements were given graphically in Fig. 6 and Fig.7.As the concentration of the graphene increased, weight and thickness values increased.

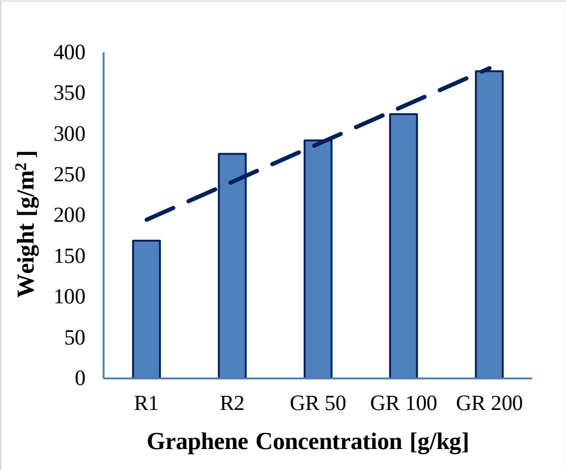

Fig. 6. Weight results depending on graphene concentration

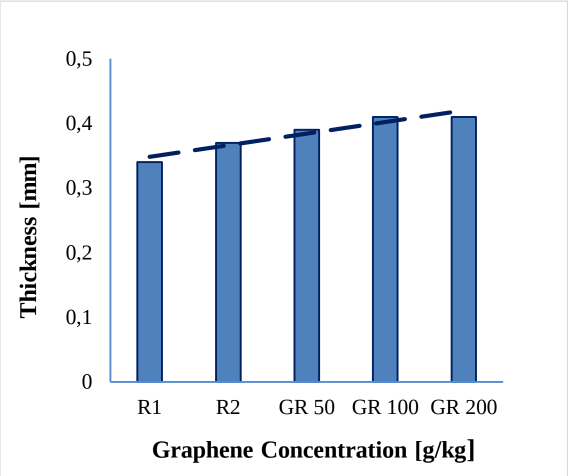

Fig. 7. Thickness results depending on graphene concentration

III. 2 Bending Rigidity Results

Coating paste which added on fabric surface causes increasing fabric stiffness. In this case, bending length and flexural rigidity increases [2].Bending length, flexural rigidity and overall flexural rigidity were calculated according to equations (1), (2) and (3) and were given in Table 5. Bending lengths were increased with increasing concentrations for both warp and weft directions.

TABLE 5
Bending length, flexural rigidity and overall flexural rigidity results

Sample Code	Bending Length (cm)	Flexural Rigidity (mg.cm)	Overall Flexural Rigidity (mg.cm)

	Warp	Weft	Warp	Weft	
R1	1.6	1.6	67.9	66.7	67.3
GR 50	2.7	2.3	549.9	355.5	442.1
GR100	2.9	2.7	774.3	610.1	687.3
GR200	3.5	3.4	1644.3	1534.7	1588.5

III. 3 Abrasion Resistance Results

Abrasion resistance test results of fabrics were given graphically in Fig. 8. The amount of weight loss in the fabric after the abrasion gives an idea about the abrasion resistance of the coating [15].

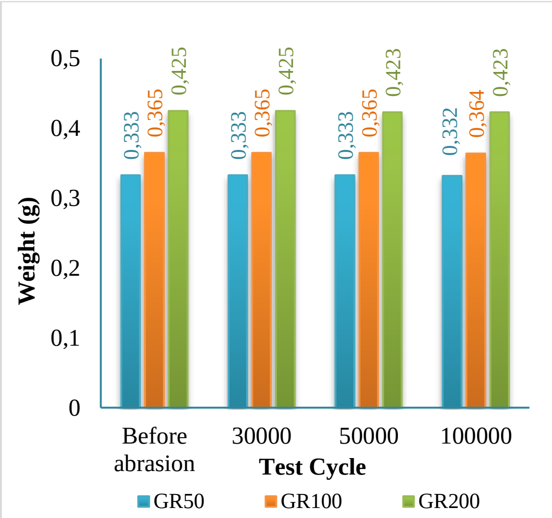

Fig. 8. Weight results depending on abrasion

According to Fig. 8 there was not any change in fabric weight for GR50, GR100 and GR200 samples after 30.000 cycles. After 50000 cycles, a weight loss of 0.47% occurred in GR200. After 100.000 cycles, weight loss of 0.30%, 0.27% and 0.47% occurred in GR50, GR100 and GR200 respectively.

III. 4 Tear Strength Results

The finishing process applied to fabric is an important factor in the tear strength of the fabric. If a process applied to the fabric prevents the movement of the yarn groups together, the fabric tears more easily. In the coated fabrics, the tear strength decreases as the movement of the yarns are eliminated [16]. Tear strength results were given in Table 6.

TABLE 6
Tear strength results

Sample Code	Tear Strength (N)	
	Warp	Weft
R_1	57.4	57.6
R_2	50.5	44.7
GR 50	52.2	51.1
GR100	50	52.9
GR 200	54	54.8

When R1 and R2 results were compared, it was seen that the coating process decreased tear strength values. However, according to the results of graphene coated fabrics, tear strength values increased compare to R2. Graphene additive had a positive effect on tear strength results.

III. 5 Bursting Strength Results

Bursting strength results were given graphically in Figure 9. When R1 and R2 values were investigated, it was seen that the coating process had affected results positively. The movement of the weft and warp yarns under the multi-directional load caused a decrease with the effect of the coating and caused the bursting strength values of the fabrics to increase [17].

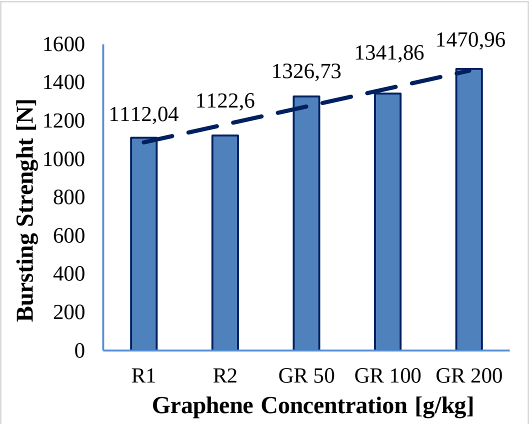

Fig. 9. Bursting strength results

IV. CONCLUSION

Performance tests of graphene coated fabrics were performed. When the weight and thickness measurement results were examined, it was seen that the weight and thickness of the fabrics were increased after coating process.

Bending length decreased and overall flexural rigidity values increased with increasing graphene concentration as expected.

According to the abrasion resistance results, an important weight loss did not occurred even after 100.000 cycles.

Although the coating process generally reduces tear strength values, ıt was concluded that graphene coating had a positive effect on tear strength values.

Bursting strength values were increased with increasing graphene concentration.

It can be seen that the graphene coating enhanced the performance properties of polyester fabrics. Besides good mechanical properties, graphene has excellent thermal, optical and electrical properties. Because of that, it is concluded that graphene coated fabrics can be used in different areas in technical textile applications. In future works, electrical and thermal conductivity properties of fabrics will be investigated.

VI. Acknowledgements

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